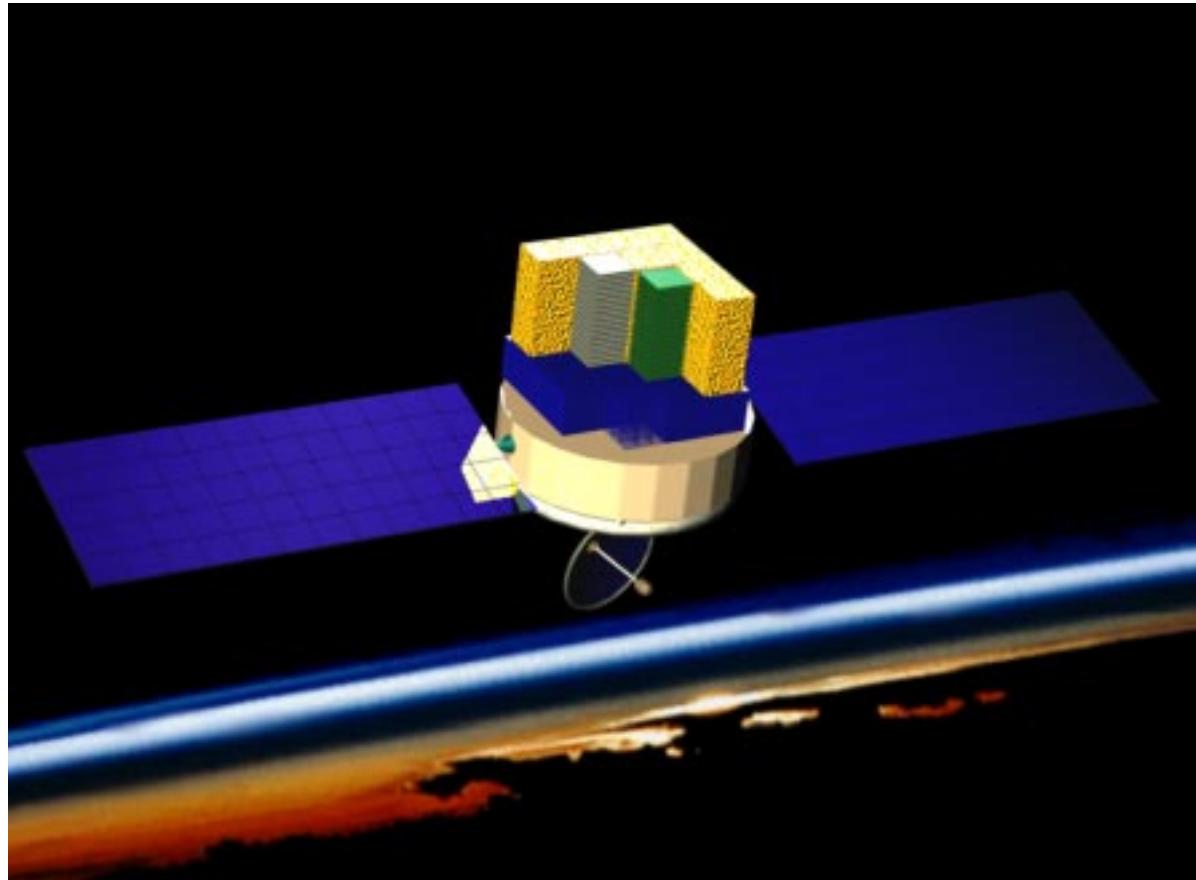


GeV Gamma Ray Astronomy in the GLAST Era



Neil Gehrels

June 26, 2000



Recent Development in U.S.

Astronomy and Astrophysics in the New Millennium NRC 10-year Report

Table 1.1 Prioritized Initiatives and Estimated Federal Costs for the Decade 2000-2010.

Ground Based	Cost (\$M)	Space Based	Cost (\$M)
Major Initiatives			
Giant Segmented-Mirror Telescope (GSMT)	350	Next Generation Space Telescope (NGST)	1000
Expanded Very Large Array (EVAL)	140	Constellation-X Observatory	800
Large-aperture Synoptic Survey Telescope (LSST)	170	Terrestrial Planet Finder (TPF)	200
		Single-Aperture Far Infra Red (SAFIR) Observatory	100
Moderate Initiatives			
Telescope System Instrumentation Program (TSIP)	50	Gamma-ray Large Area Space Telescope (GLAST)	300
Advanced Solar Telescope(AST)	60	Laser Interferometer Space Antenna (LISA)	250
Square Kilometer Array (SKA) Technology Development	22	Solar Dynamics Observatory (SDO)	300
Combined Array for Research in Millimeter-wave Astronomy (CARMA)	11	Energetic X-ray Imaging Survey Telescope (EXIST)	150
Very Energetic Radiation Imaging Telescope Array System (VERITAS)	35	Advanced Radio Interferometry between Space and Earth (ARISE)	350
Frequency Agile Solar Radiotelescope (FASR)	26		
South Pole Submillimeter-wave Telescope (SPST)	50		



Gamma Ray Large Area Space Telescope

Theme: Exploring Sites of Particle Acceleration in the Universe

- Launch in 2005
- 20 MeV to 300 GeV
- Wide-field imaging telescope
- NASA cost is \$326 M
- <http://glast.gsfc.nasa.gov/>





Mission Parameters

	EGRET	AGILE	GLAST
Energy Range	20 MeV - 30 GeV	30 MeV - 50 GeV	20 MeV - > 300 GeV
Energy Resolution ($\Delta E/E$)	0.1	1	0.1
Effective Area (peak)	1500 cm ²	700 cm ²	12000 cm ²
Field of View	0.5 sr	~ 3 sr	2.5 sr
Angular Resolution	5.8° @ 100 MeV 0.5° @ 10 GeV	4.7° @ 100 MeV 0.2° @ 10 GeV	~ 3.5° @ 100 MeV ~ 0.1° @ 10 GeV
Sensitivity (> 100 MeV)*	$\sim 10^{-7}$ cm ⁻² s ⁻¹	5×10^{-8} cm ⁻² s ⁻¹	$\sim 2 \times 10^{-9}$ cm ⁻² s ⁻¹
Mass	1810 kg	60 kg	3000 kg
Lifetime	1991 - 1997	2002 - 2005	2005 - 2010

* 2 year survey at high latitudes

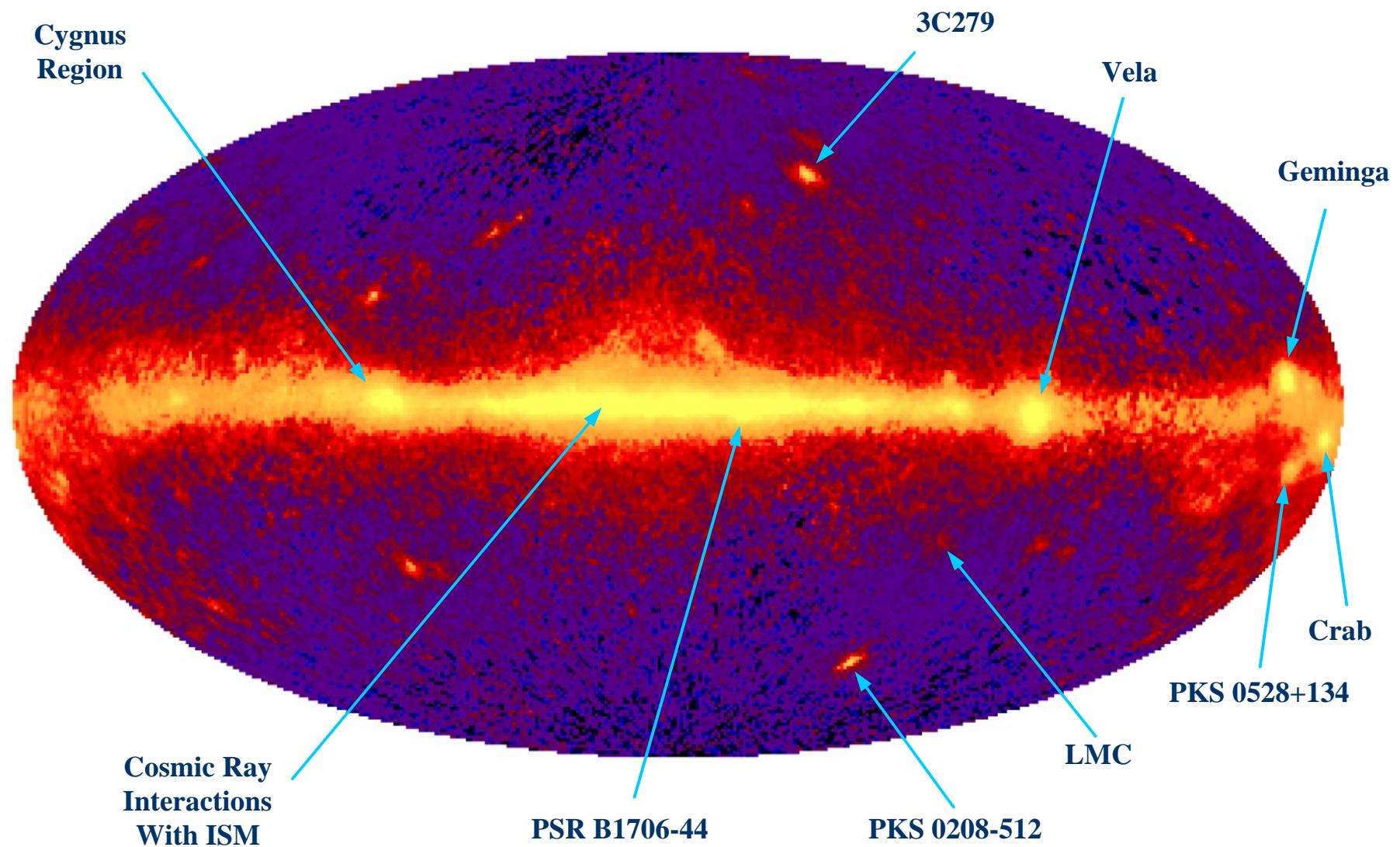


GLAST Capabilities

- Huge FOV ($> 20\%$ of sky)
- Broadband (4 decades in energy, including unexplored region > 10 GeV)
- Unprecedented PSF for gamma rays (factor > 3 better than EGRET)
- No expendables → long mission without degradation
- Large area (factor > 7 better than EGRET)
- Results in factor > 30 improvement in sensitivity



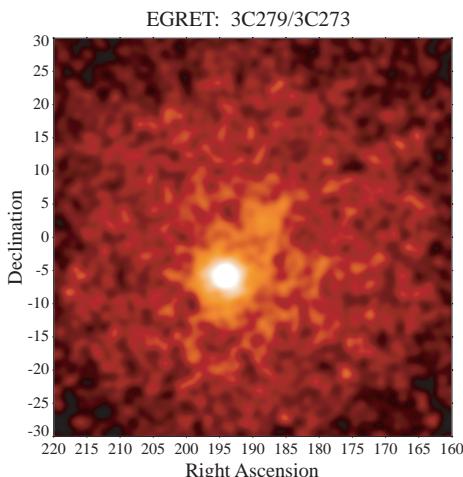
EGRET All Sky Map (>100 MeV)



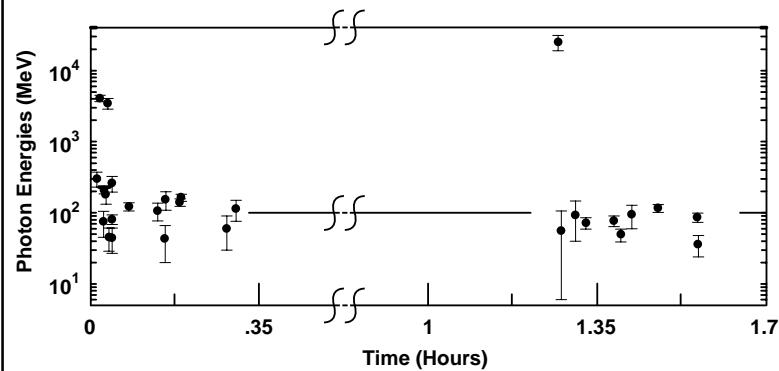


EGRET Discoveries

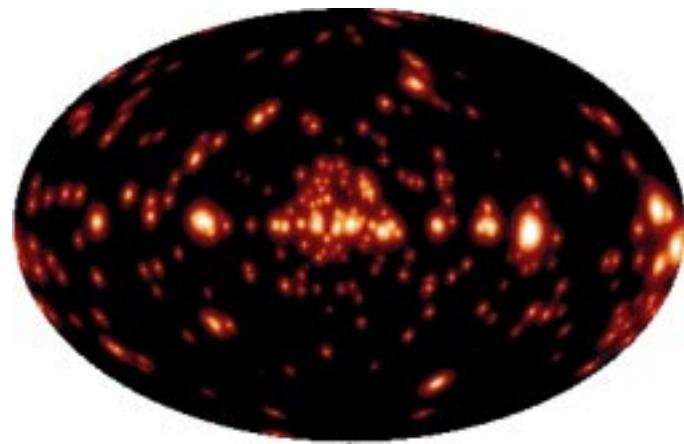
Gamma Ray Blazars



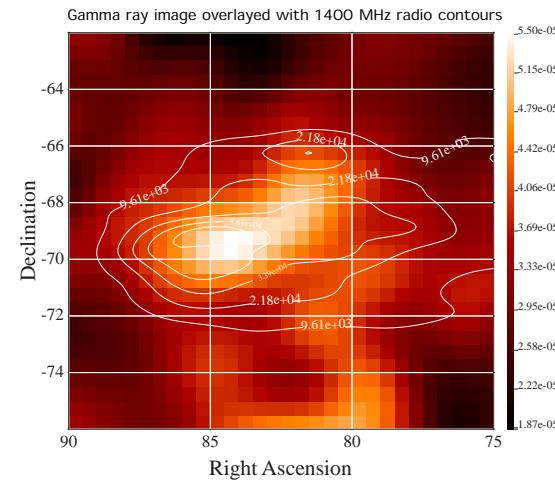
Prolonged GeV Emission from GRBs



170 Unidentified Sources



LMC Detection



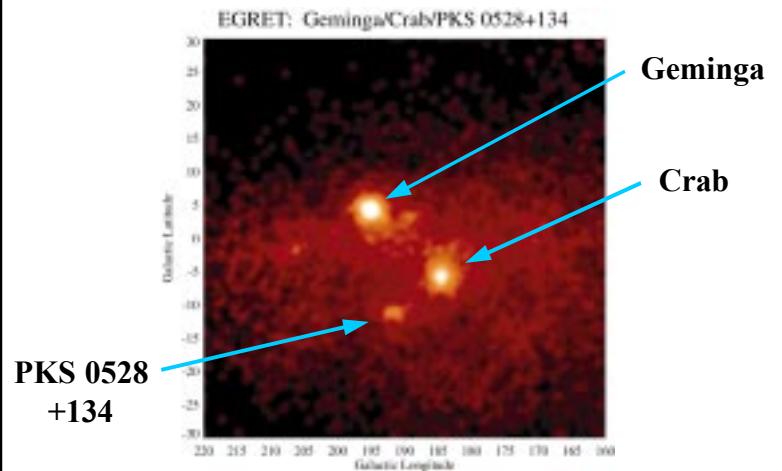


EGRET Discoveries cont.

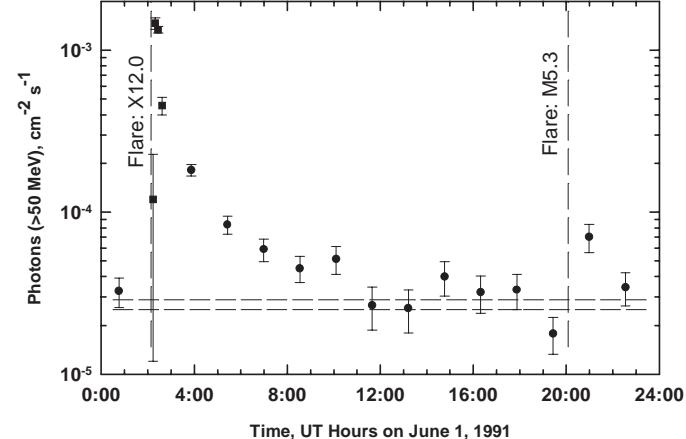
5 New Pulsars

Crab 1706-44
Vela 1055-52
Geminga
1951+32
0656 +14

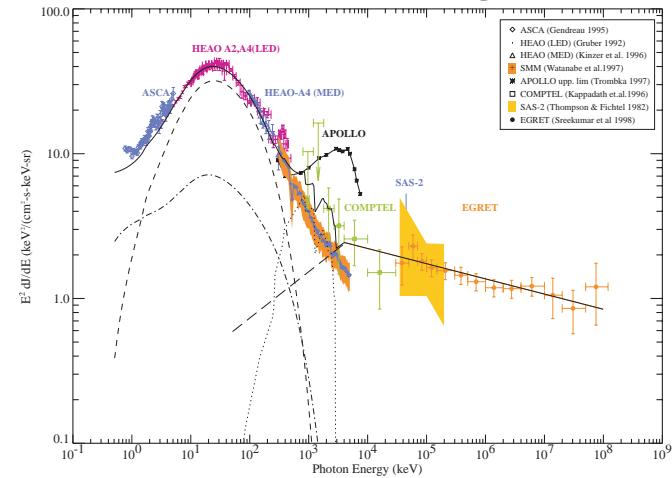
Geminga Radio-Quiet Pulsars



Prolonged GeV Emission from Solar Flares



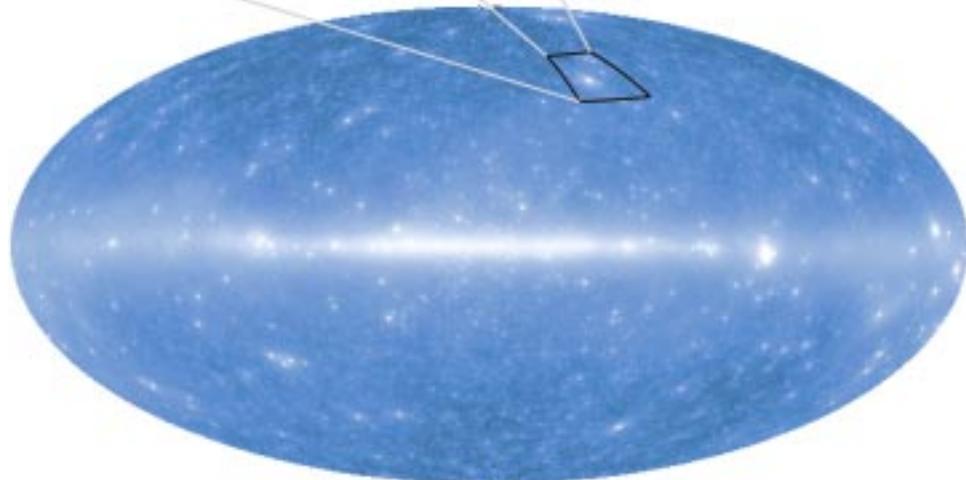
Cosmic Diffuse Background



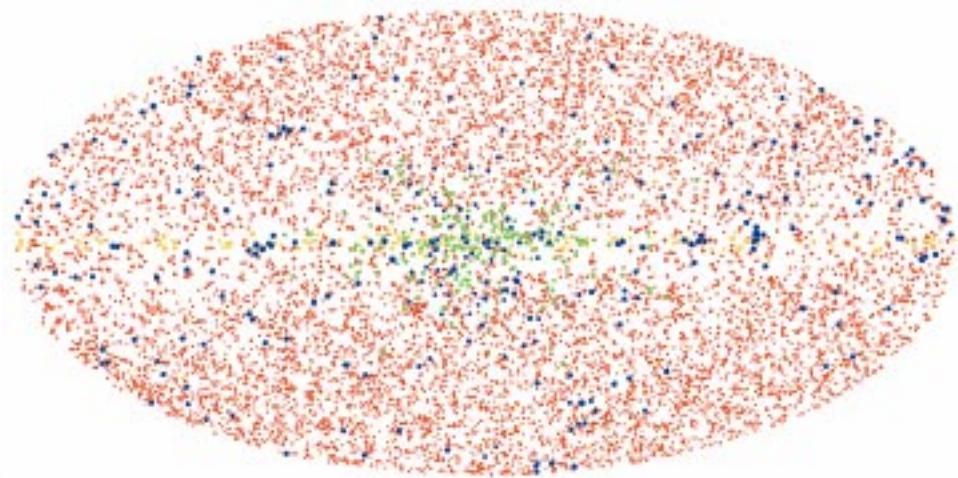


GLAST versus EGRET: All-Sky Surveys

Virgo Region ($E > 1$ GeV)



Simulated GLAST One-Year All-Sky Map ($E > 100$ MeV)



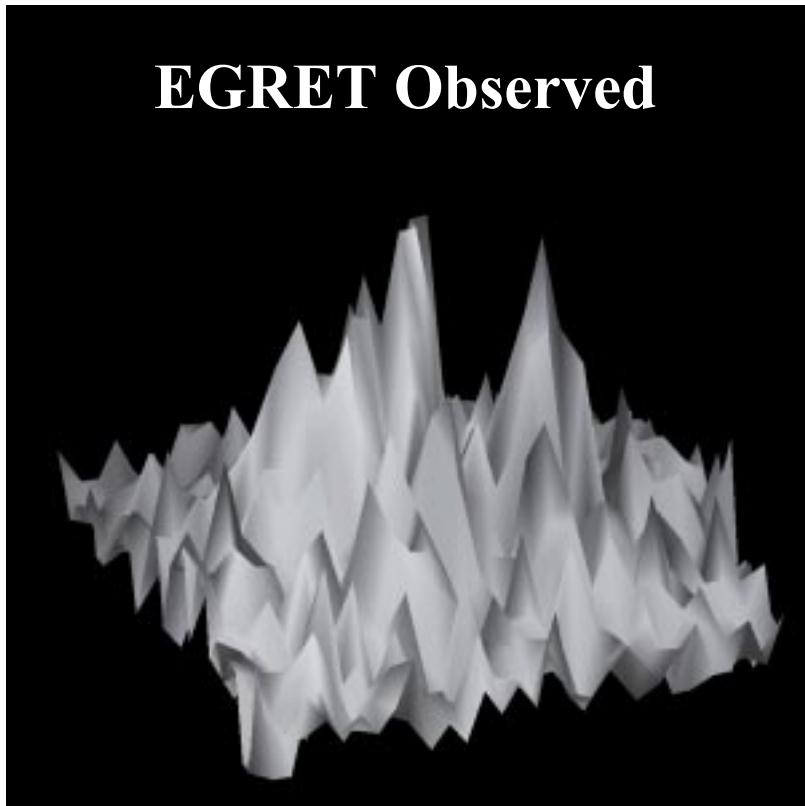
5 σ Sources from Simulated One-Year All-Sky Survey

- AGN
- 3EG Catalog
- Galactic Plane
- Galactic Halo

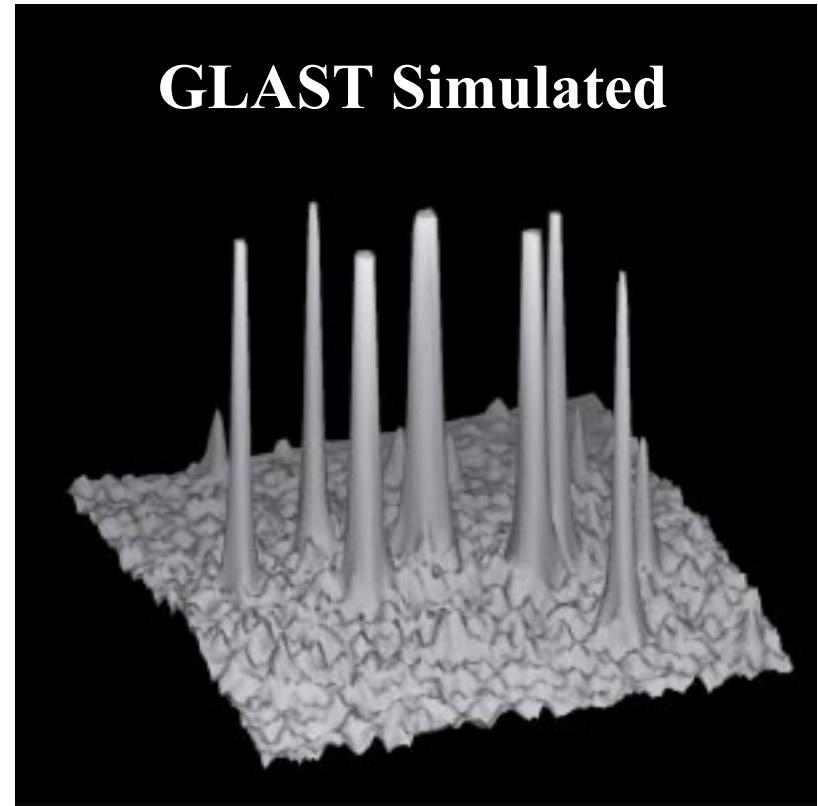


Cygnus Simulation

EGRET Observed



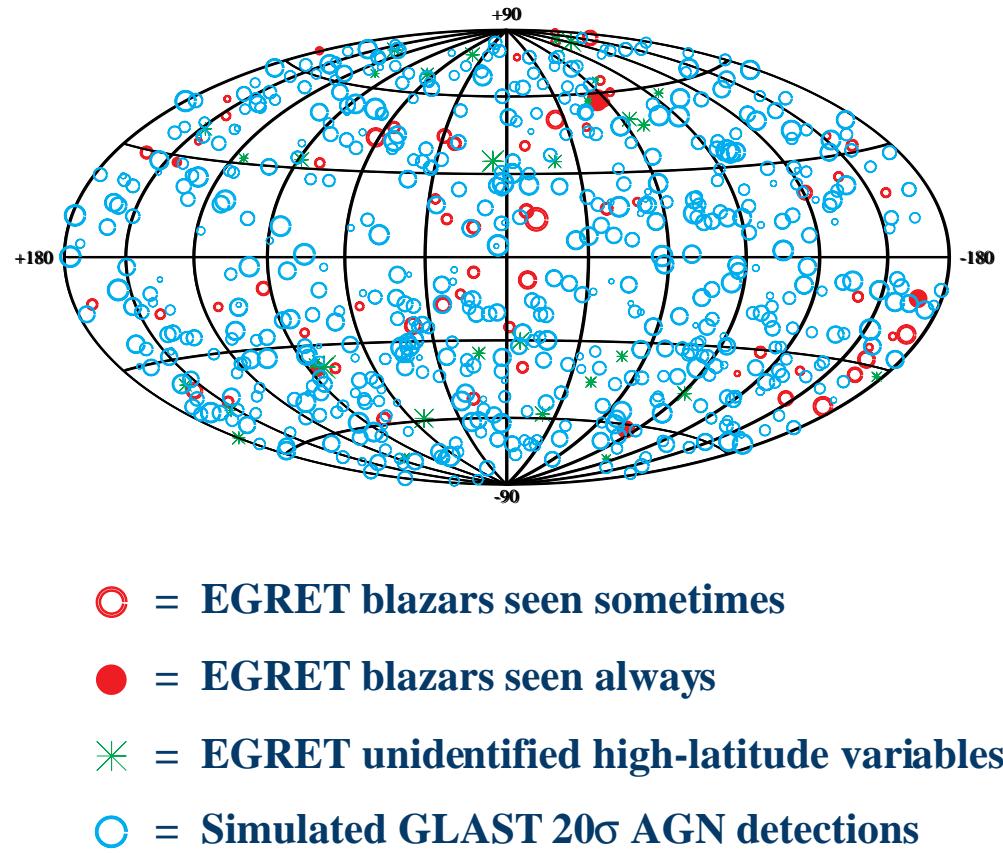
GLAST Simulated





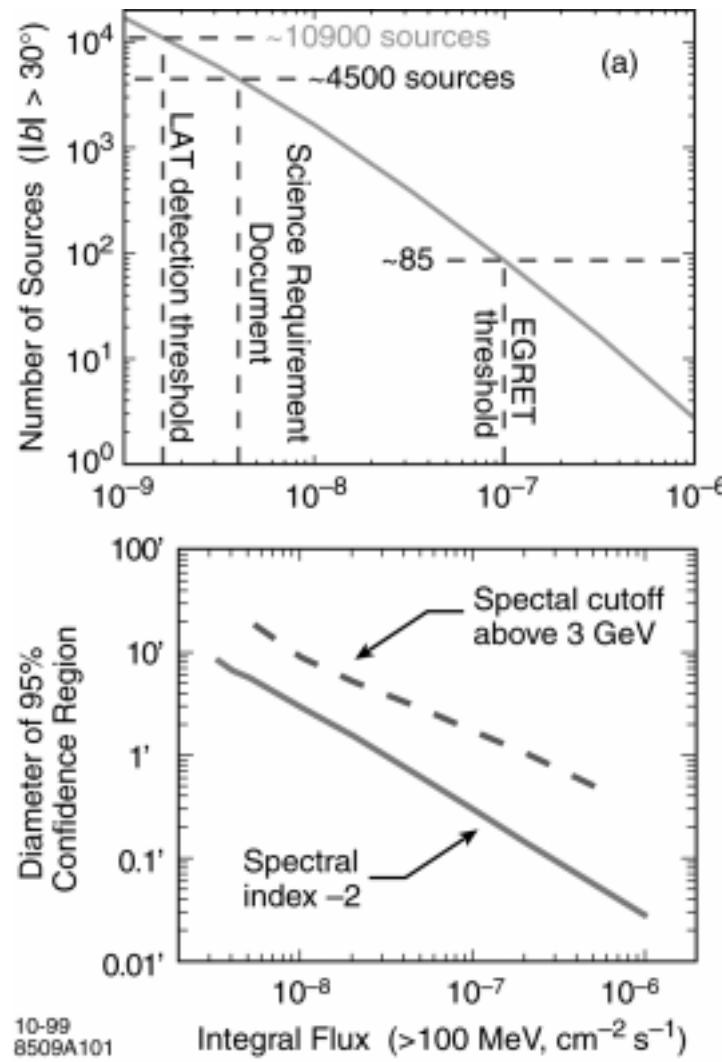
Gamma-Ray Quasars

- EGRET sees most blazars only when they flare
- What is the population of high-energy blazars?
- What is the nature of the quiescent emission?
- What is the relation to radio luminosity and variability?
- What are the high-latitude unidentifieds?





Number and Localization of GLAST AGN

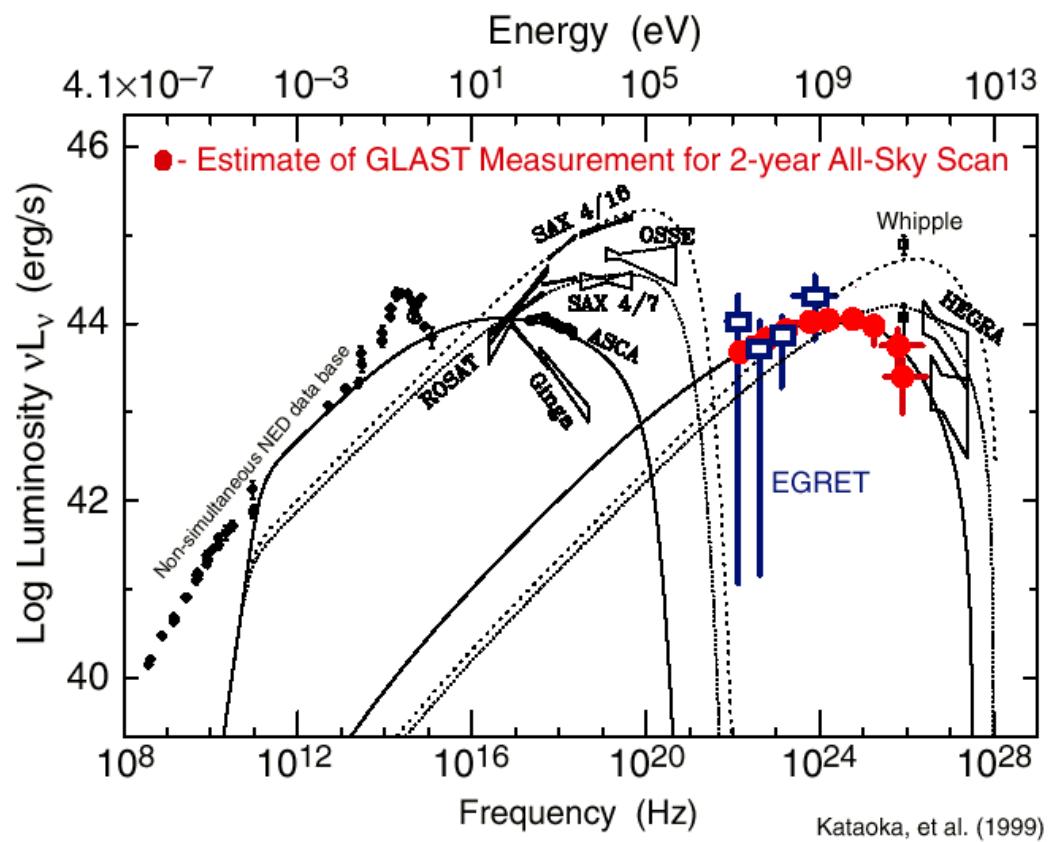




Blazar Spectra

- GLAST combined with TeV observatories will probe the complex spectra of blazars

Mrk 501

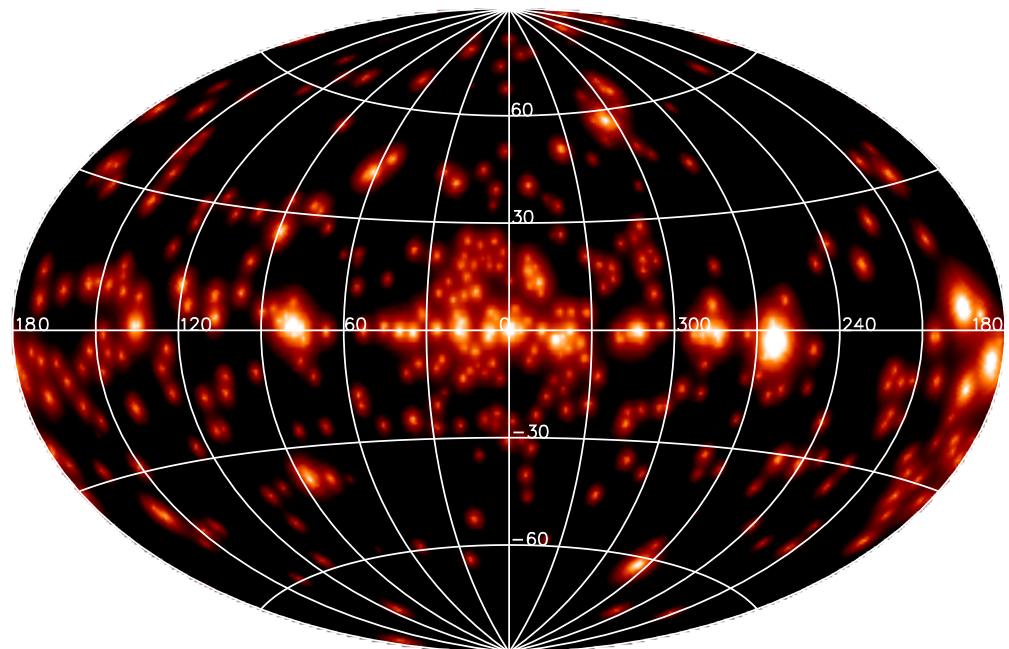




Unidentified Sources

- 172 unidentified sources in 3rd EGRET catalog
- Mystery of unidentifieds since 1970s
- Galactic unidentifieds may be SNRs, Gemingas, massive stars, molecular clouds, or new phenomenon!
- Mid-latitude sources are separate population from low-latitude sources
(Nature, March 23rd issue)

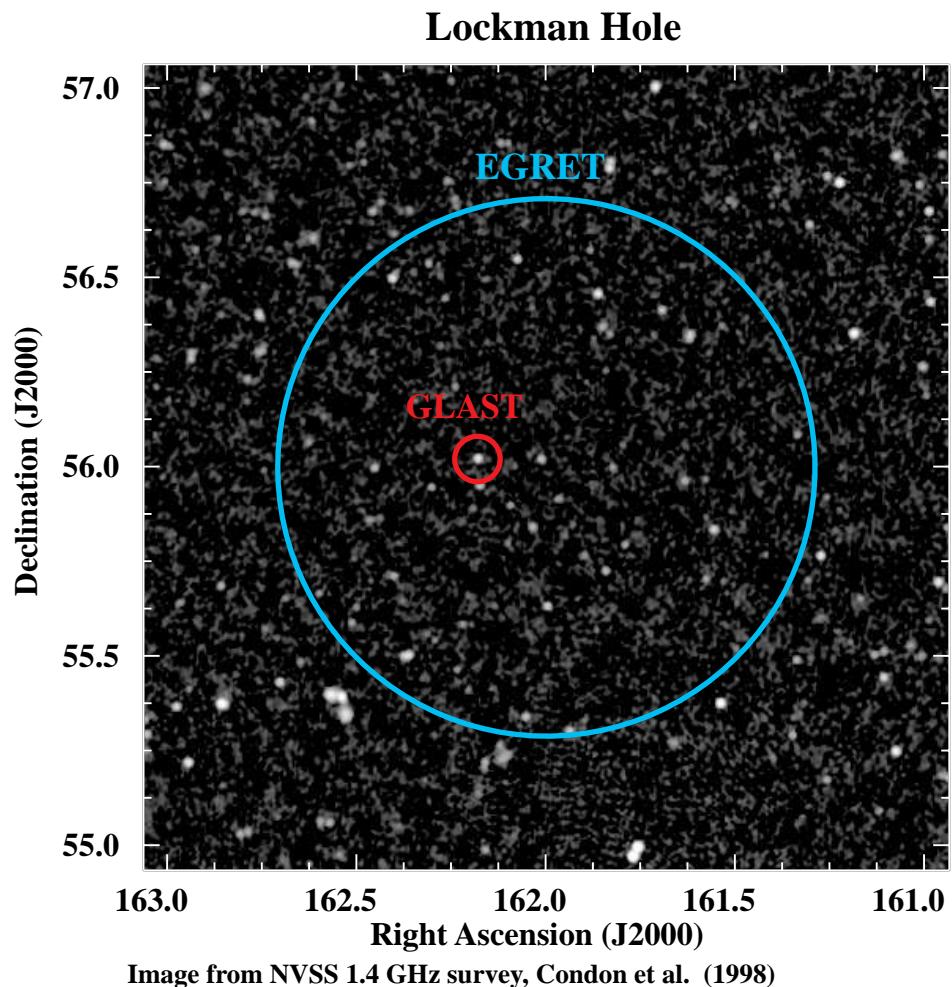
Sources in Third EGRET Catalog





Solving the Mystery of Unidentifieds With GLAST

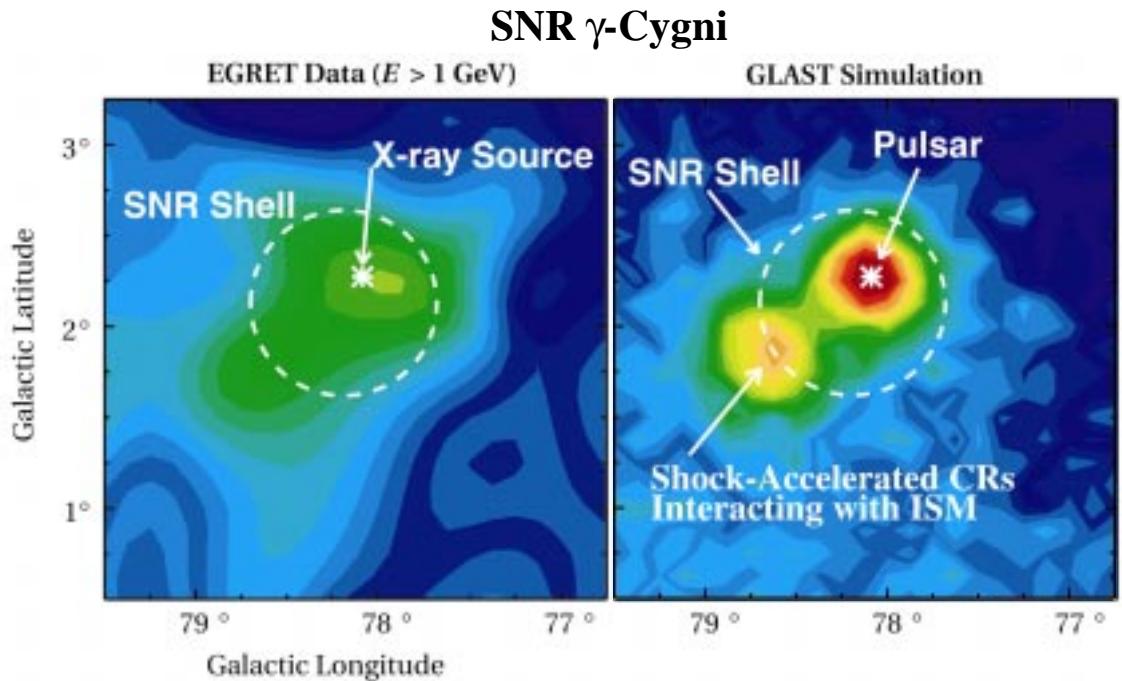
- EGRET source positions are $\sim 0.5^{\circ}$ in size, too large for counterpart searches
- GLAST will provide much more accurate source positions, 30 arcsec to 5 arcmin





SNR Origin of Cosmic Rays

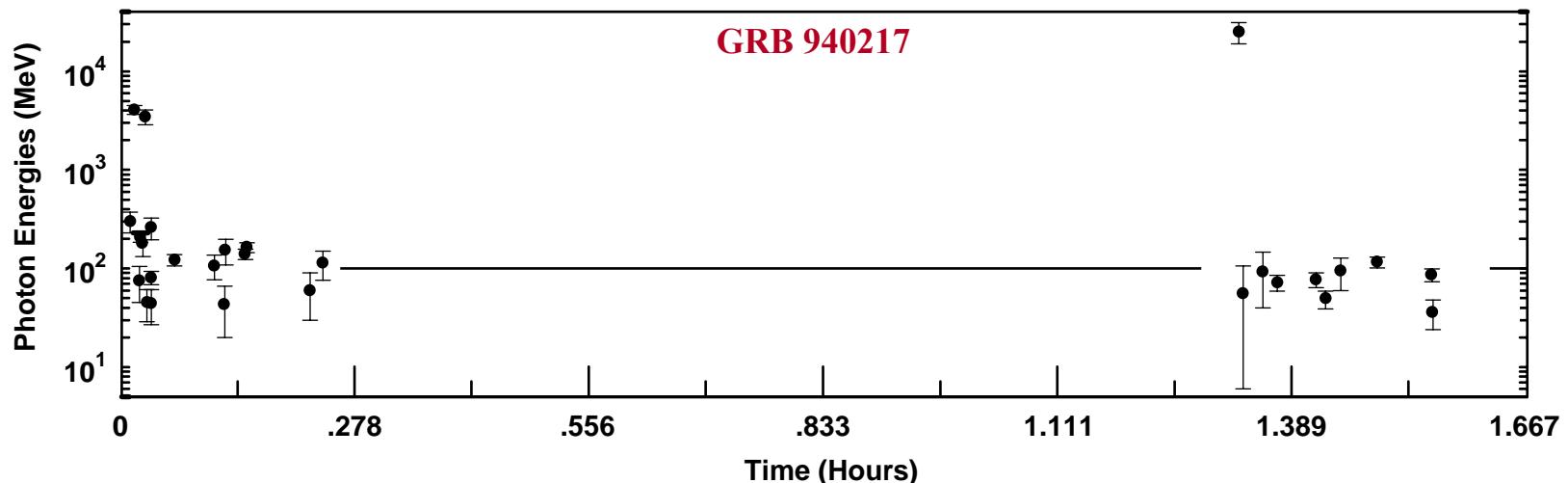
- Supernova shock acceleration models predict correct spectra and energetics
- Evidence of TeV electrons in non-thermal X-ray emission and ground-based gamma-ray observations
- Smoking gun would be an extended gamma-ray source, such as an interstellar cloud, located next to a SNR, which may be the case for Gamma Cygni
- This would provide proof that nuclei as well as electrons are accelerated as predicted



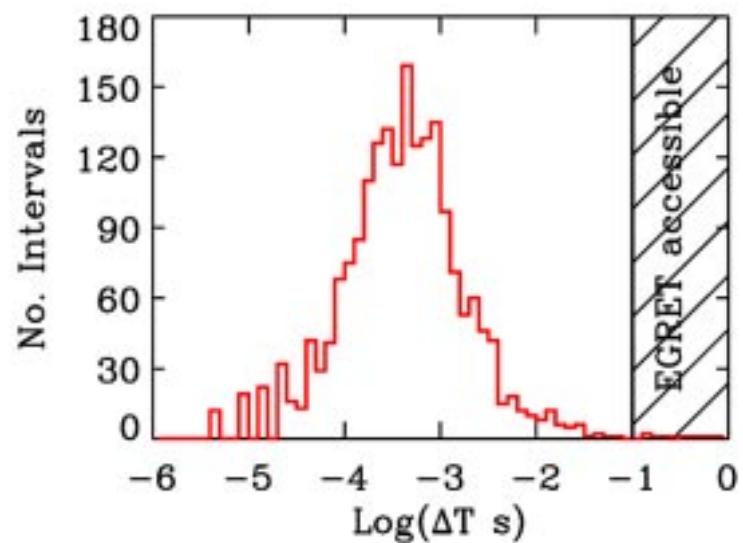
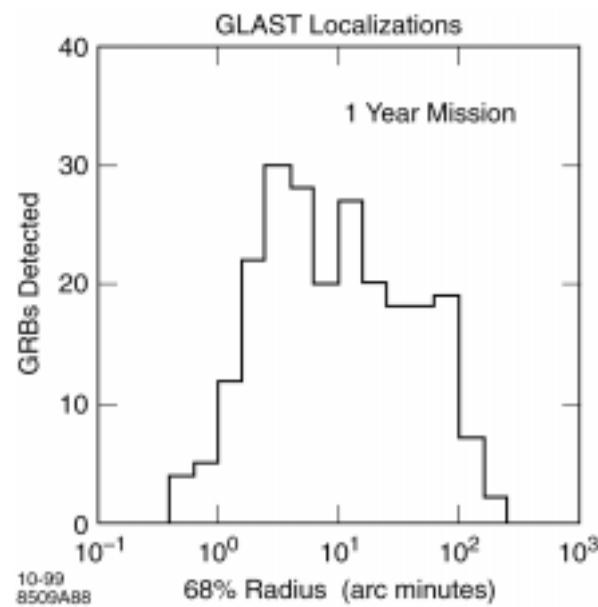


Gamma Ray Bursts

EGRET:



GLAST:



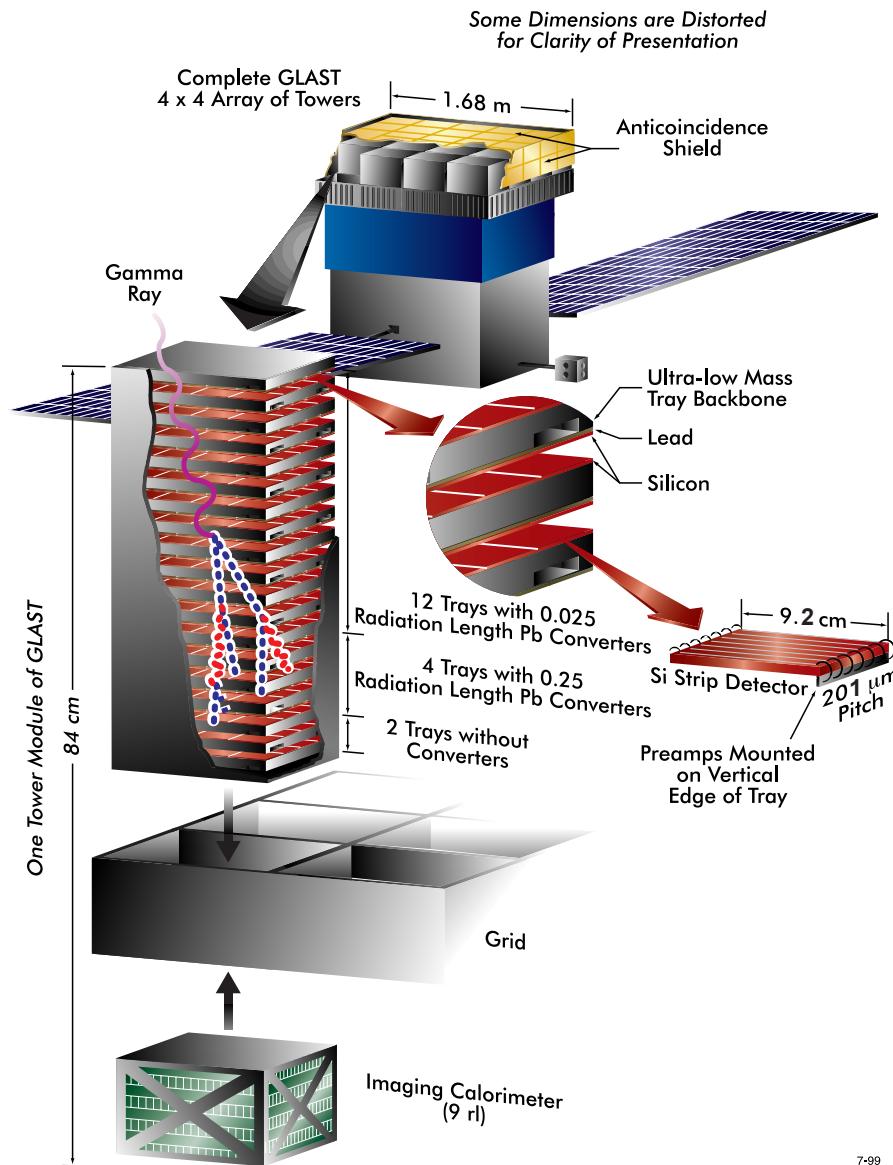


GLAST Instrument and IDS Selection

- **GLAST instruments & InterDisciplinary Scientists (IDS's) selected.**
 - **Large Area Telescope (LAT), PI: P. Michelson, Stanford**
Si Tracker: Stanford, UCSC, Japan, Italy
CsI Calorimeter: NRL, France
Anticoincidence: GSFC
Data Acquisition System: Stanford, NRL
 - **GLAST Burst Monitor (GBM), PI: C. Meegan, MSFC**
Detectors: MPE
 - NaI 5 keV - 1 MeV
 - BGO 150 keV - 30 MeV
 - **IDS's**
 - C. Dermer (NRL) - non-thermal universe**
 - B. Dingus (Wisconsin) - transients**
 - M. Pohl (Ruhr U.) - diffuse galactic**
 - S. Thorsett (UCSC) - pulsars**

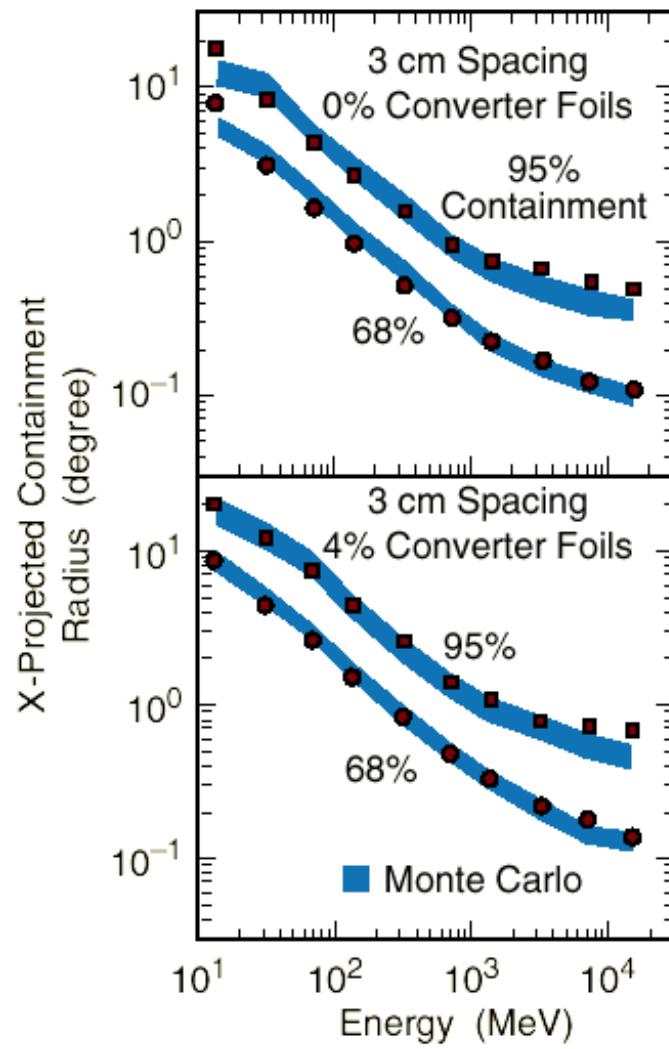
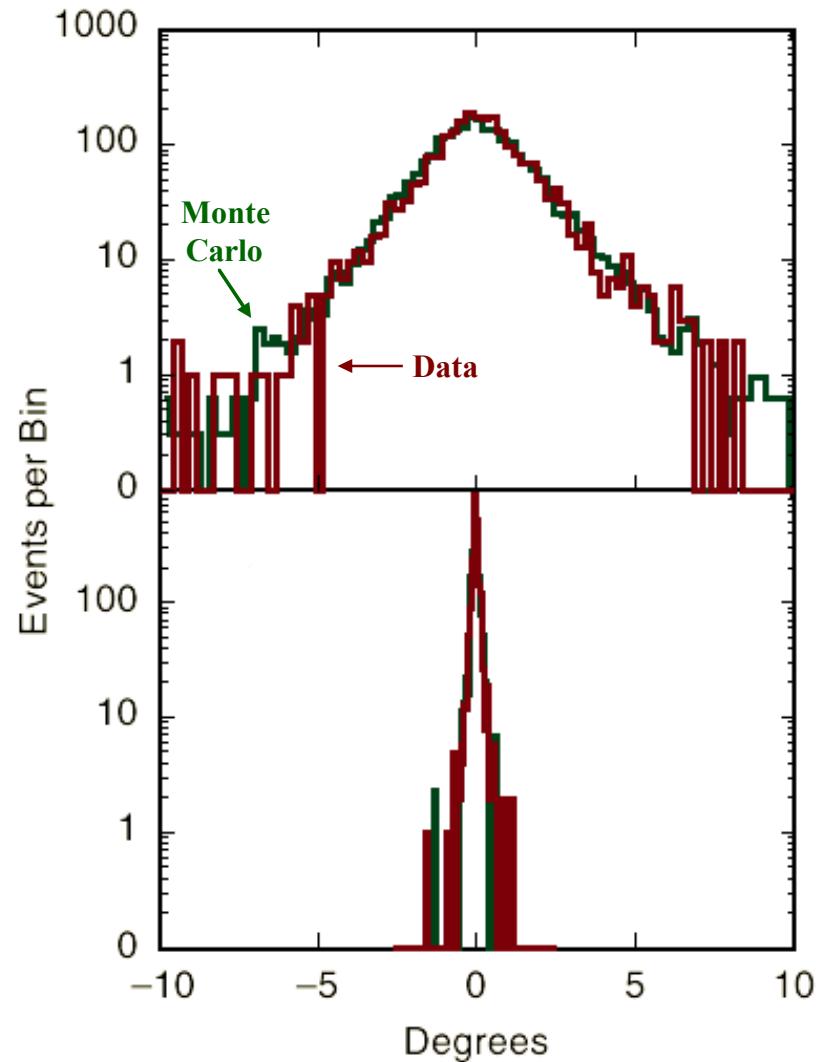


GLAST LAT



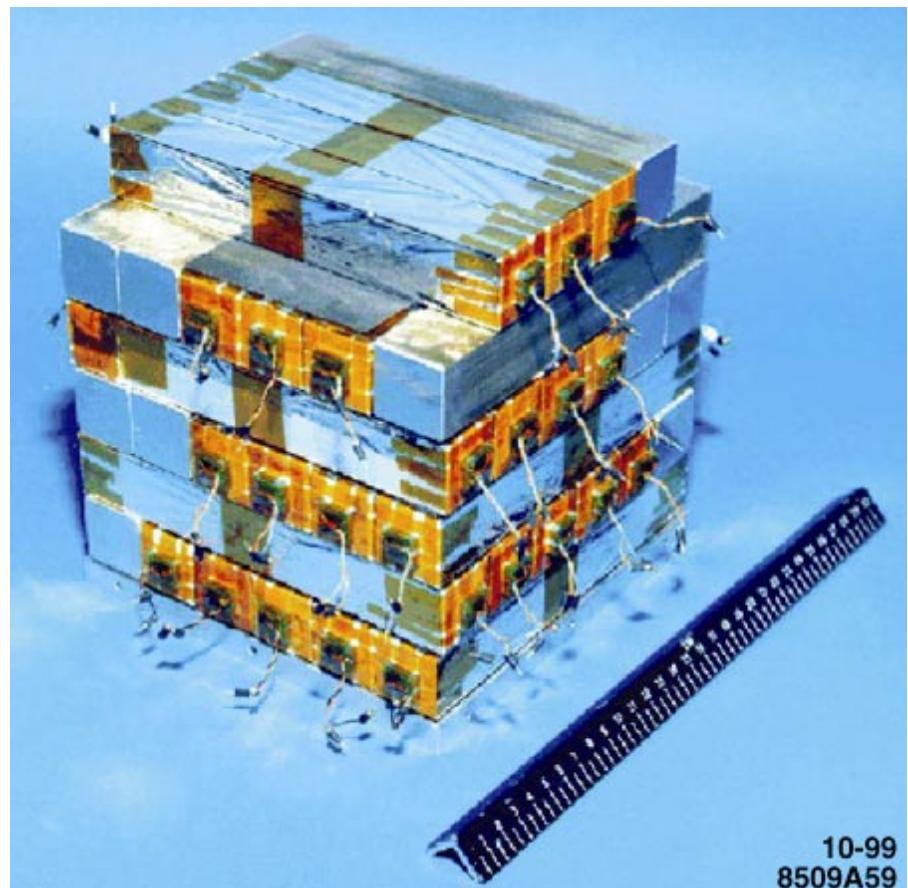


LAT Beam Test Verification



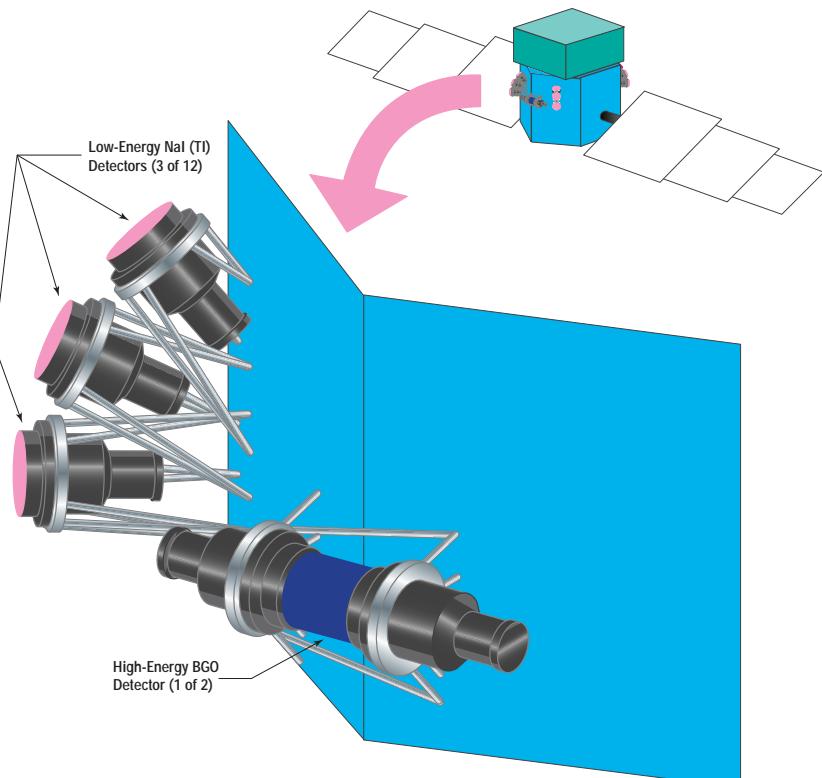


LAT Hardware

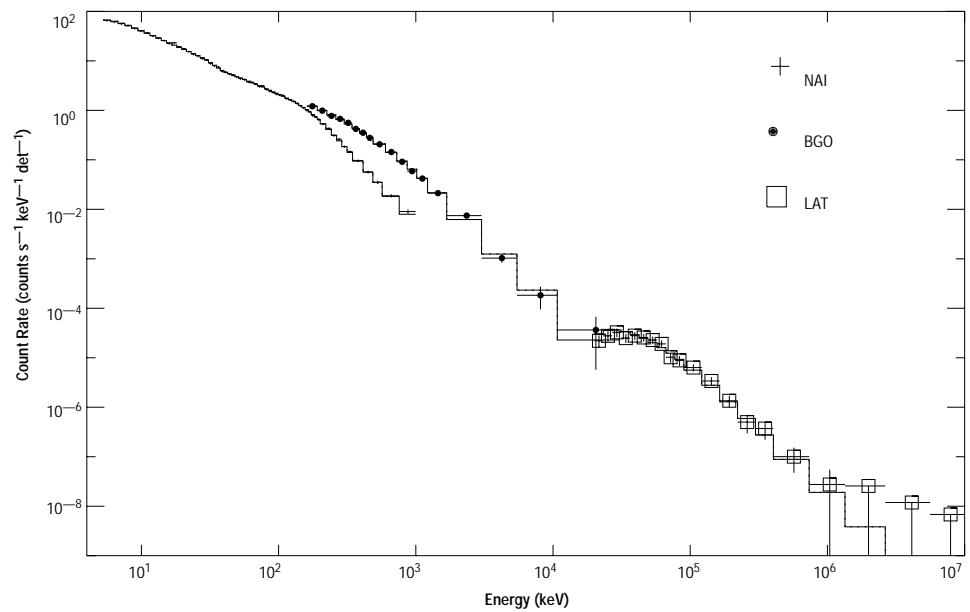




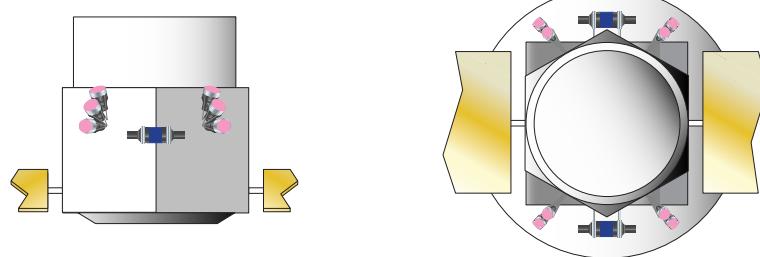
GLAST GBM



GRB 940217



LAT and GBM simulation.



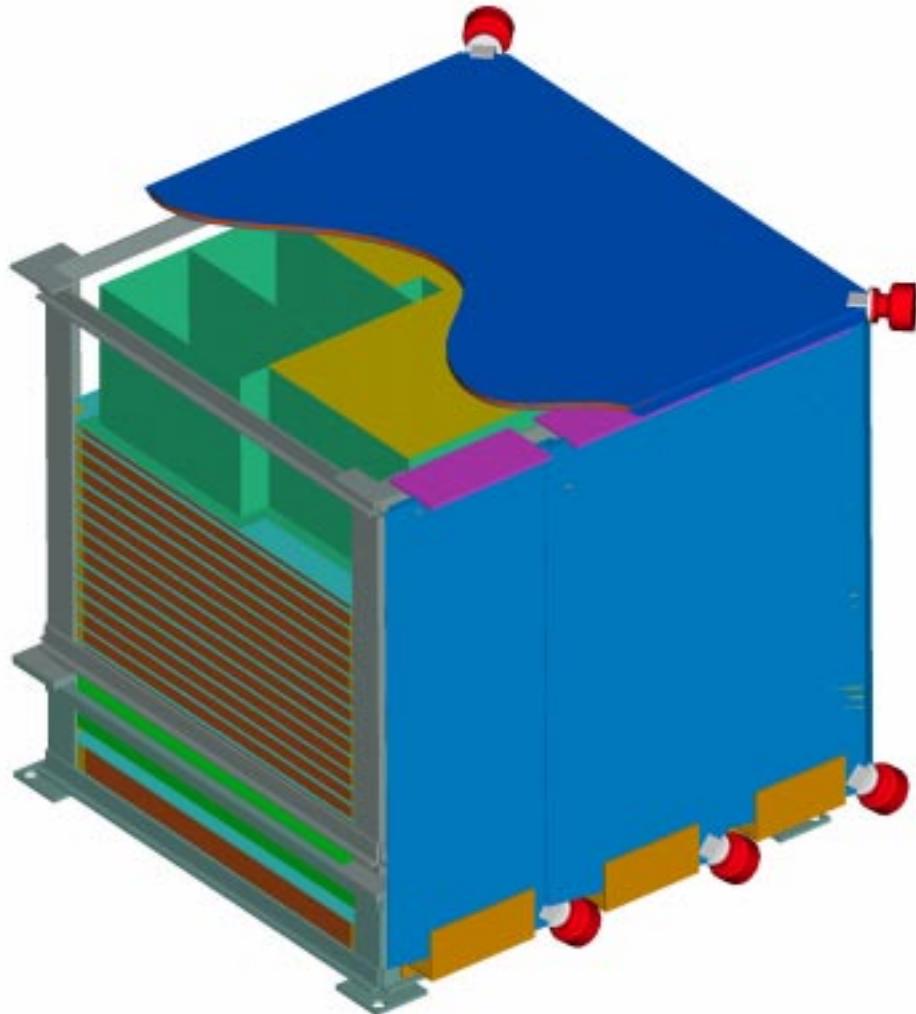


GBM vs. BATSE

Parameter	BATSE	GBM
Energy Range	25 keV - 1.9 MeV (LAD) 7 keV - 10 MeV (SD)	5 keV - 1 MeV (LED) 150 keV - 30 MeV (HED)
Detectors	NaI	NaI/BGO
FOV	Full Sky	8.6 sr
Location Accuracy	2° - 5°	1.5° - 3°
Burst Sensitivity	0.2 ph cm⁻² s⁻¹	0.6 ph cm⁻² s⁻¹



AGILE

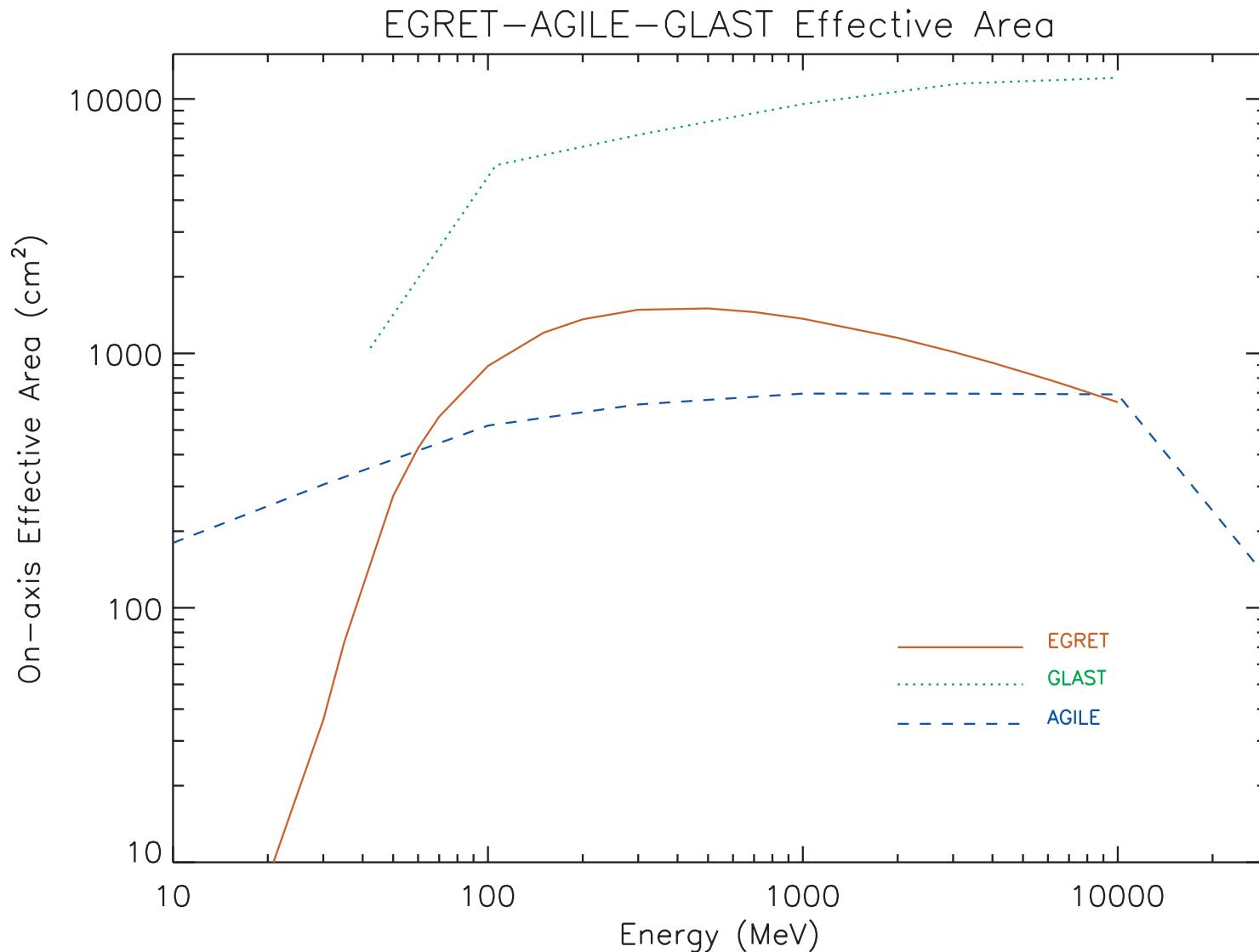


Spacecraft and Satellite Characteristics

Optimal orbital parameters	Equatorial orbit, 550 km
Possible ground station	Malindi (Kenya)
Spacecraft + payload mass	180-200 kg
Payload required power	~60 W
Downlink telemetry rate	~500 kbit/sec
Pointing configuration	3 - axes
Pointing accuracy	0.5 - 1 degree
Satellite expected life	>~ 3 years



AGILE and GLAST Performance





Space Gamma Ray Astronomy

CGRO

INTEGRAL

HETE

Swift

AGILE

GLAST

1998 2000 2002 2004 2006 2008 2010



GLAST Long-Term Schedule

